SIGMA XI QUARTERLY

Vol. XVII MARCH, 1929 No. 1

CONVENTION NUMBER

COMPTON ON "LIGHT"

CONTENTS

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Union College, Schenectady, N. Y.

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Columbia University, New York City

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Term expires January, 1931

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Term expires January, 1932

DR. LOUIS B. WILSON..........Mayo Foundation, Rochester, Minn.
Term expires January, 1933

F. E. LLOYD..........McGill University, Montreal, Canada
Term expires January, 1934

F. K. RICHTMYER..........Cornell University, Ithaca, N. Y.
Term expires 1930

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Term expires January, 1930

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Subscriptions and manuscripts should be sent to the general secretary, Edward Ellery, Union College, Schenectady, N. Y.

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SIGMA XI QUARTERLY

EDITORIAL COMMITTEE

FLOYD KARKER RICHTMYER — HENRY BALDWIN WARD
EDWIN EMERY SLOSSON — EDWARD ELLERY

VOL. XVII — MARCH, 1929 — No. 1

EDITORIAL COMMENTS

The 29th convention of our society was unique in four ways. It was held at 4 o'clock in the afternoon in order to avoid as far as possible conflict with the many sectional meetings scheduled as part of the general program of the Association. The attendance of chapter delegates was larger than at any of the three previous conventions. At the annual dinner, given jointly with the American Physical Society, approximately four hundred members and associates and guests were present. Every seat in the large auditorium of the American Museum was occupied and many were standing on the occasion of the seventh annual Sigma Xi lecture given by Professor Arthur Compton of Chicago University. The national officers are gratified at this showing. It constitutes a "record" in the history of our great organization.

* * * * * *

Comparative chapters and club representation at the last four conventions is given in the following summary:

CHAPTERS PRESENT

Kansas City, 1925, 23 of the 42 chapters, or 54.7%
Philadelphia, 1926, 24 of the 45 chapters, or 53.3%
Nashville, 1927, 27 of the 46 chapters, or 58.7%
New York, 1928, 31 of the 50 chapters, or 62.0%

CLUBS PRESENT

Kansas City, 1925, 9 of the 13, or 69.2%
Philadelphia, 1926, 4 of the 15, or 26.6%
Nashville, 1927, 6 of the 15, or 40.0%
New York, 1928, 5 of the 17, or 29.8%

The following table shows in detail how the attendance at the last four conventions was distributed among the chapters.

OFFICIAL DELEGATES AT THE LAST FOUR CONVENTIONS

Chapter	1925	1926	1927	1928
Cornell	1	1	2	3
Rensselaer	1		(1)*	1
Union		2	1	(2)*
Kansas	2		1	2
Yale	1	1	1	2
Minnesota		1	1	1
Nebraska	1	1	2	1
Ohio		1	1	
Pennsylvania	2	2	2	2
Brown		1		
Iowa	1	1	1	1
Stanford	1		1	1
California			1	
Columbia	1	1		1
Chicago	2	1	1	1
Michigan	1		2	
Illinois	2	1	2	2
Case		1	1	2
Indiana	2	1	3	
Missouri	1		1	
Colorado	1		(1)*	(1)*
Northwestern		2	1	1
Syracuse		1	1	
Wisconsin		1	(1)*	1
University of Washington	1		1	
Worcester			1	
Purdue	1		1	1
Washington University	1		(1)*	1
District of Columbia				
Texas	2		1	2
Mayo Foundation	1		(1)*	1
North Carolina				1
North Dakota	1	1		
Iowa State College (Ames)		1		1
Rutgers		1		1
McGill			1	
Kentucky	1	2	1	2
Idaho				1
Swarthmore		2	(1)*	2
Oregon				1
Virginia	2	2	1	(2)*
Johns Hopkins		1		

Calif. Inst. of Technology					
New York University	(as club)	1		(1)*	1
Univ. of Cincinnati				(3)*	
Michigan State College	(as club)	1		1	1
Arizona	(as club)	2			2
Lehigh					2
Maryland					2
Kansas State College (new)	(as club)	1	1	2	
Coll. of Med. of U. of Illinois (new)					1

* Delegates reported as appointed, but not reported present at convention.

SIGMA XI CLUBS AT THE LAST FOUR CONVENTIONS

Name	1925	1926	1927	1928
Oklahoma (Univ. of)	2	3	2	
Southern California				
Duluth				
Carleton College	1			1
University of Denver	1			
Oregon State Agri. College				
West Virginia University			1	
University of Maine				3
University of Pittsburgh		1		1
University of Wyoming			1	
University of Florida	1	1	2	
University of Rochester				1
Colo. Agricultural College				
State College of Washington	1		1	1
Univ. of South Dakota				
Louisiana State University				
University of Alabama				

At the Sigma Xi registration desk at the Association headquarters, both at Columbia University and at the American Museum, members and associates of the society were given opportunity to register, regardless of whether they were official delegates from their chapters or not. They were asked to give the chapter in which they were originally initiated and their present address. The following table gives a summary of that registration.

REPRESENTATION SHOWN BY REGISTRATION CARDS

Chapters

	Original chapter	Present affiliation		Original chapter	Present affiliation
Cornell	49	37	Purdue	8	7
Rensselaer	2	3	Washington University	8	7

	Original chapter	Present affiliation		Original chapter	Present affiliation
Union	3	3	Dist. of Columbia		
Kansas	13	6	Texas		
Yale	19	20	Mayo Foundation		
Minnesota	9	6	North Carolina	3	4
Nebraska	17	9	North Dakota		
Ohio	23	16	Iowa State College	1	4
Pennsylvania	21	33	Rutgers	4	5
Brown	13	9	McGill	1	2
Iowa	5	4	Kentucky		2
Stanford	3	4	Idaho		1
California	14	8	Swarthmore	3	2
Columbia	31	33	Oregon		1
Chicago	35	17	Virginia	1	2
Michigan	17	22	Johns Hopkins	8	11
Illinois	19	14	Calif. Inst. of Tech.	5	2
Case	1	2	New York University	1	7
Indiana	3	4	Univ. of Cincinnati	3	4
Missouri	5	3	Mich. State College	3	3
Colorado	2	1	Arizona	1	1
Northwestern	3	4	Lehigh	1	1
Syracuse	6	7	Maryland		4
Wisconsin	22	14	Kansas State College		3
Univ. of Washington	1	1	College of Med. of the Univ. of Illinois	1	
Worcester	2	3 (1 from Clark Univ.)			

Clubs

Oklahoma	2	Univ. of So. Dakota	2
Carleton College	4	Louisiana State	1
Oregon State Ag.	2	Pittsburgh	4
West Virginia	1	Wyoming	1
Univ. of Maine	2	Univ. of Rochester	3
Colo. Agri. College	2		

One member registered as at present connected with the University of Hawaii, and twenty-two as residing in Washington, D. C.

Early in January the secretary invited all the delegates who were present at the convention to comment upon the convention and the Sigma Xi meetings connected with it. It is to be regretted that not all the delegates responded to the invitation. Excerpts from the responses received to date (February 14) clearly reveal the attitude and interest of Sigma Xi members scattered over a wide area.

"An entire afternoon should be set aside for the Annual Convention.

It would be a good idea to provide a special period, probably immediately after the meeting, during which delegates and national officers could have an opportunity for personal contact and discussion. The joint dinner arrangement is a good feature."

"The hour of four o'clock for the convention is about the best that can be secured since it interferes with the other programs (or vice versa) least at that time. The dinner hour (6:00 P.M.) is too early. It should be 7:00 P.M. at the earliest. A special period before the convention should be provided for informal discussion between the national officers and delegates. Such an arrangement would be a help to the society and to the delegates. The plan of a joint dinner with one of the many organizations meeting with the Association is a good one."

"The hour of 4:00 P.M. for the convention is a good one. An after-dinner hour should be provided for continuing discussion. It would be advantageous if delegates and national officers could meet each other individually. It is preferable for Sigma Xi to hold its own dinner independently of any other organization."

"For a number of years it has appeared to me that scientists attending national meetings derive as much stimulus and pleasure from personal contacts as from scientific programs. I wonder if the interests of Sigma Xi might not be more effectively fostered by a convivial assembly of those who attend the meeting because of their primary interest in Sigma Xi. The hour for the convention (4 P.M.) is highly satisfactory and the expedition with which the routine business is dispatched is admirable. The session is too short to permit informal discussion. An informal session supplementary to the convention would permit the national officers to create interest in the society's undertakings and the delegates would go back to their chapters enthusiastic boosters. Delegates should have opportunity to voice criticism and to profit by the constructive type or convert the critic."

"It would be advisable to allow more time for the convention by making the banquet hour later. This would allow for a brief 'get-acquainted' session. The plan for a joint dinner is a very satisfactory one."

"I have attended a number of conventions of the society and felt when I left the New York meeting that it had been the best convention I had ever attended. The reduction of time from a whole afternoon to an hour and a half was particularly valuable. My

recollection of previous conventions is of a very considerable amount of talking and very little accomplished. I see no reason why Sigma Xi should not join with some other organization for a joint dinner."

"The hour (4 P.M.) for the convention is a good one but the meeting should begin promptly at that time. Six o'clock is too early for the dinner. It should be at six-thirty or seven. A joint dinner with some other society largely eliminates the individuality of our society. I do not think the plan advisable."

"An evening meeting would be very much better than what we have attempted in recent years. Certainly it should come at some other hour than 4 P.M. I heard considerable criticism with reference to the dinner. I doubt the wisdom of having joint meetings with other associations."

* * * * * *

Biographies and photographs of the officers chosen at the convention are reserved for the June issue of the QUARTERLY.

LIST OF MISSING PERSONS

Can You Help Us Locate These Members?

NAME	*CHAPTER*	*LAST KNOWN ADDRESS*
Abbe, Leslie Morgan	W. P. I. 1922	300 East Third St., Newport, Kentucky
Abbott, James Francis	Chicago 1904 Wash. 1910 Stanford 1908	2028 Hyde St., San Francisco, Calif.
Abbott, John Blackler	Purdue 1913	32 Elm St., Durham, New Hampshire
Abernethy, Wilbur Kingsley	Purdue 1916	1619 North Shore Ave., Chicago, Illinois
Abraham, Leonard Gladstone	Illinois 1923	
Ackerman, Arthur W.	Neb. 1917	E. E. Dept., Ames Emerich No. 5, Nassau Street, New York City
Ackerman, Paul C.	Michigan 1922	1110 Michigan Ave., Ann Arbor, Mich.
Ackman, Frederic Douglas (Dr.)	McGill 1923	Royal Victoria Hospital, Pine Ave. W., Montreal, Canada
Acomb, William Edward	Minn. 1902	American Steel and Wire Co., Waukegan, Wisconsin
Adams, Amy Elizabeth	Yale 1922	East Stroudsburg, Penna.
Adams, Daniel E.	Ohio 1915	Parkersburg, W. Va.
Adams, E. A.	McGill	
Adams, Elmer W.	Wis. 1923	Chem. Dept., Normal School, Pittsburg, Kansas
Adams, John Herbert	Purdue 1916	South Bend, Indiana
Adams, Lydia M.	Mich. 1904	Asst. City Bacteriologist, St. Louis, Mo.
Adler, Leon	Ill. 1917	3906 LaFayette Ave., St. Louis, Missouri
Aguerrevere, Santiago Emigdio	Stanford 1925	Tampico, Mexico
Aiken, Hugh K., Jr.	Cornell 1922	Cornell University (Dept. of Chem.), Ithaca, N. Y.
Aiyer, S. Subramanya	Wis. 1922	c/o Thomas Cook and Son, Ludgate Circus, London, England
Ajwani, Hashu J.	Iowa 1923	Shikarpur, India
Akey, Olen M.	Ohio 1921	General Delivery, San Francisco, Calif.
Albers, George Rockwell	Kansas 1896	Box 477, Los Angeles, Calif.
Albert, W. B.	Wis. 1925 m	
Aldwell, Doreen	U. of Wash. 1924 a	
Alexander, Charles Paul	Cornell 1913	419 W. Main St. (Nat. Hist. Survey), Urbana, Ill.
Alexander, Clive Morris	Brown 1911	Waxahachie, Texas
Alexopoulos, Constantine John	Ill. 1927 a	708 W. California St., Urbana, Ill.
Algeo, Murla (Miss)	Chicago 1916	
Alicante, Marcos M.	Ill. 1923	
Allen, Bennett Mills (Prof.)	Chicago 1903 Wis. 1907 Kansas	Univ. of Southern Calif., Los Angeles, Calif.
Allen, Clifford G.	Case 1917	Wellman-Seaver-Morgan Co., Akron, Ohio
Allen, E. G.	Calif. 1920	
Allen, Harry W.	Ohio 1925	1256 Hunter Ave, Columbus, Ohio
Allen, Helen Jeanette	Chicago 1919	University of Chicago, Chicago, Ill.

(OVER)

NAME	*CHAPTER*	*LAST KNOWN ADDRESS*
Allen, J. M.	McGill	Chemistry Building, McGill University, Montreal, P. Q., Canada
Allen, Paul W.	Ill. 1922	Dairy Dept., Cornell University, Ithaca, New York
Alsdorf, Frederich C.	Ohio 1905	Adams Hotel, Phoenix, Ariz.
Altshuler, Henry I.	Calif. 1918	
Ambridge, Douglas White	McGill 1923	
An, Carl Henry	Worcester 1924	U. S. Bureau of Standards, Washington, D. C.
Anderegg, Louis Theodore (Prof.)	Ames 1924	Dept. of Dairy Bacteriology, Iowa State College, Ames, Iowa
Anderson, A. L.	Idaho 1923	
Anderson, Andrew John Albert	Ill. 1916	913 Irving Park Blvd., Chicago, Ill.
*Anderson, Edla V	Minn. 1921	
Anderson, Edward W.	Iowa 1923	
Anderson, Ernest Gustaf	Neb. 1915 Cornell 1917	Cold Spring Harbor, N. Y.
Anderson, Frank Oscar	Missouri 1921	Dept. of Physiology, Univ. of Missouri, Columbia, Mo.
Anderson, Gordon Rowen	Mich. 1920	3755 N. Meridian St., Indianapolis, Ind.
Anderson, Henry Clay	Mich. 1903	1610 Washtenaw Ave., Ann Arbor, Mich.
Anderson, John Arl.	Wis. 1923	
Anderson, Paul Johnson	Cornell 1912	14 Ladoga, Indiana
Anderson, Robert Griffeth	McGill 1923	
Anderson, Rupert S.	U. of Wash. 1920	Cooper Union Institute, New York City
Anderson, William Elmer	Neb. 1918	4923 Kenmore Ave., Chicago, Ill.
Andervont, Howard Bancroft	J. H. U. 1926	
Andrew, Victor John	Chicago 1928 a	4999 Indiana Ave., Chicago, Ill.
Andrews, Albert LeRoy	Cornell 1915	
Andrews, James C.	Columbia 1917	Du Pont Chemical Co., Wilmington, Del.
Andrews, Launcelot Winchester	Iowa 1900	Andrews Chemical Works, Davenport, Iowa
Andrews, Philip	Colo. 1921	(Mexican Crp. S. A.), Fresnillo, Zacatecas, Mexico
Andrews, Rufus Adams	Yale 1923	352 Temple St., New Haven, Conn.
Andros, Stephen O.	Ill. 1914	
Angle, E. E.	Neb. 1918	New York Hospital, New York City
Annis, Russell Kaye	Ohio 1921	38 Lincoln Ave., Mt. Clemens, Mich.
Anthony, Charles Gilbert	Union 1913	
Anthony, George	Ohio 1922	103 W. 10th Ave., Columbus, Ohio
Archer, Robert S.	Mich. 1916	1627 Delmont Ave., Cleveland, Ohio
Arlitt, Ada Hart	Chicago 1915	Bryn Mawr College, Bryn Mawr, Penna.
Armstrong, Jeannette (Mrs. John C. Goodale)	Mich. 1919	340 Englewood Ave., Detroit, Mich.
Arnold, Howard C.	Ill. 1914	4906 McPherson Ave., St. Louis, Missouri
Arthur, John Morris	Chicago 1920	
Asami, Giochi	Wash. 1920	Waimeo, Kauai, Hawaii

MINUTES OF THE MEETING OF THE EXECUTIVE COMMITTEE OF SIGMA XI, NEW YORK CITY, DECEMBER 28, 1928

The annual winter meeting of the Executive Committee was held in the office of Dean George B. Pegram, Columbia University, Thursday, December 28, 1928. The meeting was called to order at 2:00 P.M. by President Moulton. Those present were: President Moulton, Secretary Ellery, Treasurer Pegram, Professor Ward, Dr. Whitney, Professor Baitsell, Professor Richtmyer, Mr. Davies.

Business was transacted as follows:

1. UNIVERSITY OF WYOMING:

A request from the group of petitioners at this university that the regular procedure regarding petitions be waived, and that the group be permitted to present a formal printed petition without first presenting the usual informal petition had been presented to the committee prior to the meeting and was given further careful and detailed consideration.

In view of the fact that since action on a formal printed petition could not be taken until December, 1929, even if the request of the group to waive the usual procedure were granted, no time would be saved; and in view of the further fact that possible petitions from groups in other institutions had already reached a like stage, and these groups were presenting informal petitions for consideration at the annual Spring Meeting of the committee, it was

Voted—To reiterate the action taken at the meeting in Chicago, April 12, 1928, namely, that the Sigma Xi Club at the University of Wyoming be requested to present an informal petition for consideration at a future meeting of the committee.

2. UNIVERSITY OF ROCHESTER:

In response to the vote taken at the meeting in Chicago, April 12, 1928, the petitioning group at the University of Rochester presented an informal petition. After full consideration, it was

Voted—To take the next step in the procedure for petitions, and President Moulton was empowered to appoint an official visitor.

3. At this point in the deliberations of the committee it was found that the time remaining before the opening of the Annual Con-

vention at 4 P.M. was so limited that only routine business could be transacted. It was therefore

Voted—That consideration of other informal petitions and of the reports of official visitors appointed at the Chicago meeting, April 12, 1928, be put over to the Spring Meeting.

4. The president presented a brief report of the work of his office in connection with petitioning groups, formation of clubs, etc. (The report appears on page 34.)

5. The Secretary presented excerpts from his annual report. (The report in full appears on page 35.)

6. The Treasurer presented the summations of the financial transactions of his office during the calendar year. (The complete report appears on page 40.)

7. The Secretary was requested to send to members of the committee copies of informal petitions prior to the meeting of the committee at which such informal petitions are to be considered.

8. SPRING MEETING OF THE COMMITTEE:

An invitation from the Yale Chapter to hold the annual Spring Meeting in New Haven was received, and it was unanimously

Voted—That the annual Spring Meeting of the Executive Committee be held in New Haven at 6 P.M., Friday, April 19; further, that the invitation to be present at the annual initiation and dinner of the Yale Chapter, Saturday, April 20, be accepted.

9. The meeting adjourned at 4:10 P.M. for the annual Convention of the Society.

EDWARD ELLERY, *Secretary*

PROCEEDINGS OF THE TWENTY-NINTH CONVENTION OF THE SIGMA XI

The Twenty-Ninth Convention of the Society of the Sigma Xi was held in the lecture room of the Physics Laboratories, Columbia University, New York, December 28, 1928.

President Moulton called the business session to order at 4:15 P.M., and appointed the Committee on Credentials as follows:

Professor H. J. Creighton, Swarthmore
Professor G. W. Hunter, Rensselaer
Professor W. H. Schoewe, Kansas

The Committee received the credentials of delegates and reported the following chapters represented:

Cornell*	R. C. Gibbs
	H. P. Weld
	H. H. Whetzel
Rensselaer*	G. W. Hunter
Union†	P. I. Wold
	D. R. Harper
Kansas*	A. J. Mix
	W. H. Schoewe
Yale*	A. F. Hill
	Leigh Page
Minnesota*	W. S. Cooper
	J. T. Tate
Nebraska*	N. A. Bengston
Ohio	
Pennsylvania*	T. D. Cope
	H. S. Oberly
Brown*	
Iowa*	Walter Loehwing
Stanford*	A. F. Rogers
California	
Columbia	
Chicago*	E. S. Bastin
Michigan	
Illinois*	A. C. Bevan
	C. R. Griffith
Case*	T. M. Focke
	D. C. Miller
Indiana	

Missouri	
Colorado†	W. B. Pietenpol
Northwestern*	C. D. Hurd
Syracuse	
Wisconsin*	R. A. Brink
University of Washington	
Worcester	
Purdue*	J. H. MacGillivray
Washington University*	E. S. Reynolds
District of Columbia	
Texas*	H. T. Muller J. T. Buckholz
Mayo Foundation*	Hiram E. Essex
North Carolina*	O. Stuhlman
North Dakota	
Iowa State College*	J. C. Gilman
Rutgers*	R. C. H. Heck
McGill	
Kentucky*	M. N. States G. C. Bassett, alternate
Idaho*	Ella Woods
Swarthmore*	H. J. Creighton M. Garrett
Oregon*	H. B. Yocum
Virginia†	L. G. Hoxton J. K. Roberts
Johns Hopkins	
California Inst. of Technology	
New York University*	H. W. Stunkard
University of Cincinnati	
Michigan State College*	Victor Gardner
Arizona*	J. G. Brown A. E. Douglass
Lehigh*	J. B. Reynolds B. L. Miller
Maryland*	C. O. Appleman F. E. Gardner E. S. Johnston
Kansas State College	
Coll. of Medicine, Univ. of Illinois*	George B. Hassin

* Delegates present at the Convention.
† Delegates not present at the Convention.

Clubs

Oklahoma	
Southern California	
Duluth	
Carleton*	C. H. Gingrich

University of Denver.................	
Oregon State College.................	
West Virginia University.............	
University of Maine*.................	C. R. Phipps William Dove Donald Folsom
University of Pittsburgh*............	Alfred E. Emerson
University of Wyoming...............	
University of Florida.................	
University of Rochester*.............	T. Russell Wilkins
Colorado Agricultural College.........	
State College of Washington*.........	J. B. Magness
University of South Dakota...........	
Louisiana State University............	
University of Alabama...............	

Thirty-one chapters and five clubs were represented.

Three chapters had notified the national secretary of the appointment of delegates who were not at the Convention.

Sixteen chapters had not notified the Secretary of the appointment of delegates and were not represented at the Convention.

Officers were present at the Convention as follows: *President* F. R. Moulton, Chicago; *Secretary* Edward Ellery, Union; *Treasurer* George B. Pegram, Columbia; *Executive Committee,* W. R. Whitney, General Electric Company, Schenectady; George A. Baitsell, Yale; C. E. Davies, New York; F. K. Richtmyer, Cornell.

The account of the proceedings of the Twenty-Eighth Convention of the Society at Nashville, December 27, 1927, published in the March (1928) QUARTERLY, was approved as printed.

President Moulton gave his annual report which appears on page 34.

The annual report of the Secretary was read and it appears on page 35.

The annual report of the Treasurer was presented and referred to an auditing committee, to be appointed by the President. (This report appears on page 40.) Subsequent to the convention President Moulton announced the appointment of F. W. Hehre and W. A. Curry as the auditing committee.

Mr. Davies, Chairman of the Alumni Committee, reported the meeting of the Sigma Xi Alumni in Chicago, April 12, 1928, and stated that the New York group was meeting with the Convention delegates and guests at the dinner following the Convention. He spoke encouragingly about the interest of the Alumni and the prospects for increased activity during 1929.

Treasurer Pegram offered the following resolution:

Resolved, That it is the sense of the Convention that for 1929, in order that every dollar contributed by Alumni members and associates may be devoted to grants for research, no part of the expenses of the Secretary's office is to be charged against the Alumni Contributions.

After some questions and references to the Treasurer's report, the Convention unanimously adopted the resolution.

The Nominating Committee, consisting of C. E. McClung (Pennsylvania) and H. W. Stunkard (New York University), presented the following report: For the remaining year of the present biennium, as President, F. R. Moulton (Chicago). For member of the Executive Committee for the ensuing five years, F. E. Lloyd (McGill). For member of the Alumni Committee for the ensuing five years, Clarence F. Hirshfeld, Detroit Edison Company.

It was voted that the report of the Nominating Committee be adopted, and that the Secretary be empowered to cast a ballot for the officers named.

The Secretary announced that the ballot had been cast, and declared the officers duly elected.

Upon motion by Treasurer Pegram, the Convention voted that the usual assessment on the several chapters of $1.00 per enrolled member and associate be levied for 1929.

Professor H. H. Whetzel spoke for the Cornell Chapter on the question of "What Science Does Sigma Xi Represent?" (Prof. Crew's article in the March, 1928, QUARTERLY) and offered the following resolution:

WHEREAS, It is not desirable at this time to attempt to define scientific research in terms of either method or subject matter,

BE IT RESOLVED, That noteworthy contribution to (or promise of notable accomplishment in) scientific investigation shall constitute eligibility for election to Sigma Xi regardless of the field in which the candidate may be working. Each separate chapter shall be responsible for the interpretation of this principle in election to its membership or associateship.

After many questions and considerable discussion, the Convention voted to lay the resolution on the table until the 1929 Convention.

Consideration of the proposed amendment to the Constitution to omit the date of the installation of the chapter from the engraving on the insignia of the Society was deferred to the 1929 Convention.

The Convention adjourned at 5:40 P.M. to meet at the American Museum of Natural History for the Annual Dinner.

ANNUAL DINNER

The Annual Dinner of the Society was given in Flying Bird Hall of the American Museum of Natural History, where amid unusual and beautiful surroundings members and guests to the number of about four hundred sat down to a delicious menu provided by the superintendent of the cafeteria of the Museum. Members of the New York Sigma Xi Alumni Association and of the American Physical Society were present by invitation. President Moulton called upon Professor P. W. Bridgman, Vice-President of Section B of the Association, and Professor Karl T. Compton, President of the American Physical Society, to present greetings from their respective organizations. Arrangements for the dinner were admirably made and carried out by a committee of New York alumni, and by Professor H. W. Webb, Secretary of the American Physical Society.

At the close of the dinner, the company adjourned to the auditorium of the Museum for the Seventh Annual Sigma Xi Address, delivered by Professor Arthur Compton of the University of Chicago, on "What Is Light?"

EDWARD ELLERY, *Secretary*

WHAT IS LIGHT*

ARTHUR H. COMPTON

From the time that the ancient Greeks told each other about the shafts of light shot by Apollo, men have concerned themselves with what light is. Together with its sister problem, the nature of matter, this question presents the fascination of a fundamental mystery. During the last generation a rich mine of new information regarding light has been worked, and the remarkable discoveries that have thus appeared have seemed to make the subject a suitable one to present before the Society of Sigma Xi. Yet in spite of this new information light remains as perhaps the darkest of our physical problems, and as such may well be reviewed before the Physics section of the American Association.

As long ago as the seventeenth century, Newton defended the view that light consists of streams of little particles, shot with tremendous speed from a candle or the sun or any other source of light. At the dawn of the nineteenth century, however, experiments were performed which were thought to give positive evidence that light consists of waves. Maxwell interpreted them as electromagnetic waves, and in such terms as we have ever since been explaining, light rays, x-rays and radio rays. We have measured the length of the waves, their frequency and other characteristics, and have felt that we know them intimately. Very recently, however, a group of electrical effects of light has been discovered for which the idea of light waves suggests no explanation, but whose interpretation is obvious according to a modified form of Newton's old theory of light projectiles.

Review of the Various Electromagnetic Radiations

When the physicist speaks of light he thinks not only of those radiations which affect the eye. He refers rather to a wide range of radiations, similar to light in essential nature, but differing in the quality described variously by the terms color, wave-length or frequency.

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At one end of this series of radiations are the wireless, or radio rays, with which in recent years we have become so familiar. There is an important point regarding these rays which I should like to call to your attention. When one strikes the strings of a mandolin, they are set into vibration, and produce up in the surrounding air the waves which affect our ears and cause the sensation of sound. Investigation shows that the sound waves in the air vibrate with the same frequency—the same number of times per second—as do the strings on the mandolin. In precisely the same way, when electrically charged condensers are discharged, an oscillation of the electric charge is set up, which gives rise to electric waves just as the vibrating string produced sound waves. These electric waves are caught by an electric ear at the rear of the room, and are there transformed through a loud speaker into the noise which offends your tone-conscious ears.

The emitted electric waves have the same frequency as the oscillating source. Though visible light is known to be essentially the same kind of thing as these electric waves, we have long sought in vain for any oscillator which would emit light waves having the same frequency as that of the oscillating source. It was only when Heisenberg introduced a new kind of mechanics, differing radically from the classical ideas of Newton, that we found that the atom vibrates with certain "overtones" whose frequency is that of the light waves which come from it. This is one of the serious difficulties with the wave conception of light which could only be solved by a fundamental change in our ideas regarding how things work.

Measured in term of the length of a wave, electric waves extend from many miles in length, down through the radio waves of say 300 meters, to the very short waves resulting from tiny sparks, which may be no more than a tenth of a millimeter in length. These rays overlap in wave-length the longest heat waves radiated by hot bodies, and may be detected and measured by the same instruments. A familiar source of such heat rays is the reflector type of electric heater, the kind that warms one side of us in a chilly room. The greater part of these heat rays are intermediate in wave-length between the shortest electric waves and visible light. Such a heater, however, glows a dull red, showing how its rays extend into the visible region.

Ordinary visible light is well represented by the radiation from a carbon arc. I shall pass its rays through a lens and prism, and

project them onto this screen. We see how it is made up of rays of many colors, from red to violet, which the prism has separated from each other. Beyond the red end of the spectrum lie the heat rays. Indeed if we should place a radiometer just beyond the red end of the spectrum, we should find it strongly affected by the heat rays from the arc. The question arises, are there similar radiations beyond the violet which we are unable to see?

In order to answer this question, let me bring up a fluorescent screen of platinum barium cyanide. Notice the brilliant green glow extending far beyond the violet light on the ordinary screen. Evidently our failure to see light in this region is not because there is no light, but because our eyes are insensitive to rays of this type. The fluorescent screen changes their color so that we can see them. These are the *ultraviolet rays* of which we have heard so much recently in connection with summer sunshine and prevention of rickets.

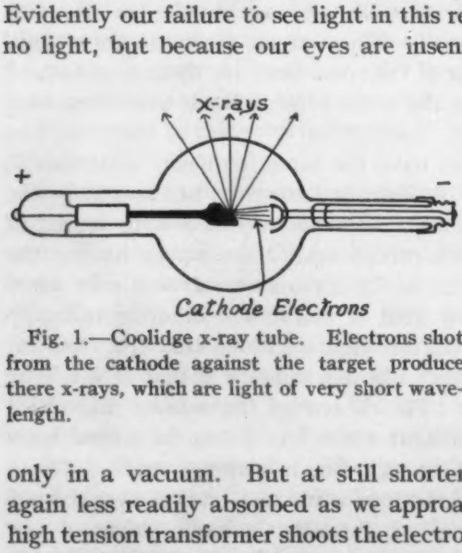


Fig. 1.—Coolidge x-ray tube. Electrons shot from the cathode against the target produce there x-rays, which are light of very short wave-length.

As one goes farther into the ultraviolet the rays become rapidly absorbed by air, and can be studied only in a vacuum. But at still shorter wave-lengths the rays are again less readily absorbed as we approach the region of x-rays. A high tension transformer shoots the electrons at high speed from the hot wire cathode against the tungsten target and these x-rays are emitted (Fig. 1). It is like shooting a rapid fire gun at a steel plate. The bullets represent the electrons shot from the cathode, and the noise resulting when the bullets bang against the plate represents the x-rays.

Just as in the case of ultraviolet light, these x-rays do not affect our eyes. Their existence can, however, be shown by placing in their path the same screen which we use to detect the ultraviolet rays. Notice how it lights up when I apply the voltage from the transformer. That these rays are of the same nature as light is shown by the fact that we have found it possible to reflect and refract them to polarize and diffract them. They are indeed light of ten thousand times shorter wave-length.

One of the most important properties of x-rays is their ability to ionize air and make it electrically conducting. Let me show this by the following experiment. You see projected on the screen the gold leaf of an electroscope. Notice, when I turn on the x-rays, how quickly the leaf falls, showing that the electroscope has lost its charge. This is due to the breaking up by the x-rays of the oxygen and nitrogen atoms in the air. Precisely the same thing happens to the atoms in one's body when in the path of x-rays. This it is which makes possible x-ray burns and x-ray therapy.

Such ionization can also be produced by the gamma rays from radium. Let us charge the electroscope again. This time, instead of turning on the x-rays, we shall bring up a small tube containing a milligram of radium. Again the leaf falls as the electroscope loses its charge. These rays are much less intense than the x-rays, as is

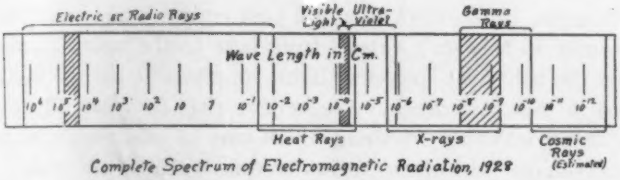


Fig. 2.—Complete spectrum of electromagnetic radiation on a logarithmic scale. Visible light is only a small but very important part of this spectrum.

shown by the slowness with which the leaf drops. They are, on the other hand, much more penetrating. Whereas x-rays may be half absorbed in an inch of water, it takes a foot of water to absorb half of these gamma rays from radium, corresponding to the much shorter wave-length of the radioactive rays.

But the end is not yet. There exists a kind of highly penetrating radiation which is especially prominent at high altitudes, and is supposed to come from some source outside the earth. These *cosmic rays*, as they are called, will penetrate ten or twenty feet of water before they are half absorbed. Unfortunately I cannot show them to you here, for it would take all night for such rays to make an appreciable effect on our electroscope.

In Figure 2 we see graphically how these different rays are related to each other. At the extreme left I have arbitrarily started the spectrum at wave-lengths of 18 kilometers, which is the wave-length

of certain trans-Atlantic wireless signals. There is no reason why longer waves could not be produced if desired. The electric waves continue in an unbroken spectrum down to 0.1 mm., rays recently studied at Cleveland by the late Dr. Nichols and Mr. Tear. Overlapping these electric waves are the heat rays, which have been observed from about 0.03 cm. to 0.00003 cm., including the whole of the visible region. The heat rays in turn are overlapped by the ultraviolet rays, produced by electric discharges; and these reach well into the region described as x-rays. Beyond these are in turn the gamma rays and the cosmic rays. Thus over a range of wave-lengths of from 2×10^{-13} cm. to 2×10^{6} cm. there is found to be a continuous spectrum of radiations, of which visible light occupies only a very narrow band.

The great breadth of this wave-length range will perhaps be better appreciated if we expand the scale until the wave of a cosmic ray has a length equal to the thickness of a post card. The longest wireless wave would on this scale extend from here to the nearest fixed star.

When the physicist speaks of light, he refers to all the radiations included in this vast range. We believe that they are all the same kind of thing, and that anything which may be said about the nature of the rays in one part of this region is equally true of the rest.

It will perhaps be profitable to pause at this point and ask ourselves what type of evidence we may hope to get regarding the nature of radiation. When men began to inquire regarding what sound is, it was possible for them to feel the vibrations of the sounding bodies in many cases, and sometimes even to feel the vibrations set up by the sound itself. The sound thus *acts as if* it were a wave motion. When later we found it possible to photograph the shadow cast by a sound wave, no one could reasonably question the existence of the waves. There seems to be no possibility of seeing or photographing a light wave or a light corpuscle as we can a sound wave or a bullet in flight. If, however, light consists of waves, it should act as waves do; and if it consists of corpuscles it should act as do corpuscles. This is probably as far as we can go.

Light Consists of Waves

There are many ways in which light acts like a wave in an elastic medium. Such elastic waves move with a speed which is the same for all wave-lengths and all intensities, just as does light. Waves, light, light rays, can be reflected and refracted. The polarization of light

is a property characteristic of the transverse waves in an elastic solid. It is true that if one examines the constancy of the speed of light in detail, difficulties arise; for it is found that its speed is the same relative to an observer no matter how fast the observer is going. This would not be true if light were a wave in an ordinary elastic medium. Maxwell's identification of light as electromagnetic waves, however, removes this difficulty.

The crucial test for the existence of waves, however, has always been that of diffraction and interference. You have doubtless at some time amused yourselves by dropping pebbles into a pond, and watching the ripples spread out. Perhaps two pebbles fell in at once.

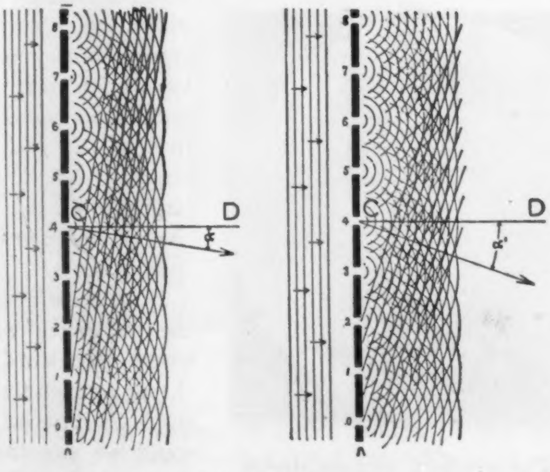


Fig. 3.—Diagram of the diffraction of waves by a grid.

In some places the crests of the two sets of ripples would come together and reinforce each other. Elsewhere perhaps the crests of one set of ripples would fall on the troughs of the other and both would be neutralized. Suppose we should drop a whole row of pebbles at once into the pond. The effect would be like that shown in Figure 3. In this figure we imagine a series of waves passing through a succession of openings in a grid. After passing through, the crests of the emerging wavelets recombine to form a new wave going straight ahead. But in addition, the wavelet just emerging from one opening may combine with the first wave from the next opening, the second from the next, and so on, forming a new wave-front inclined at a

definite angle to the first. The angle between these two waves, as you see from this diagram, is determined by the distance between successive waves—i.e., the wave-length—and by the distance between successive openings in the grid. The figure at the right shows how the emergent wave may combine with the second wave from the adjacent opening, the fourth from the second opening, and so on, and form a wave front propagated at a larger angle.

That such a variety of wave formation is not purely imaginary is shown in Figure 4, which is a photograph of ripples on the surface of mercury, taken after they have passed through a comb-like grid. Notice how one group of waves combines to form a wave-front going straight ahead. But in addition, on either side of the central beam, we find two beams forming where the paths from successive openings in the grid differ by one wave-length. Out at a larger angle we see even the second order of the diffracted beam.

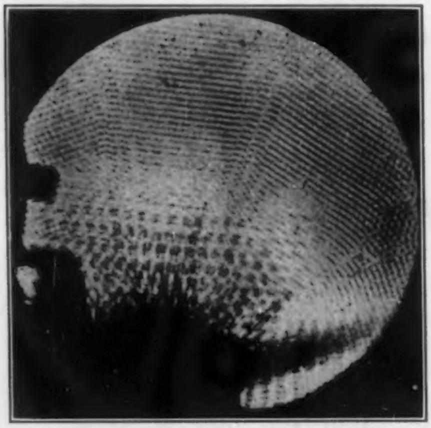


Fig. 4.—Photograph of mercury ripples diffracted by a grid.

If we were unable to see the separate waves, but knew the kind of grid through which the beam of ripples had passed, not only could we say that this is the way the beam should be split up if it consists of waves, but we could even tell what the wave-length of the ripples must be in order to give these particular angles between the diffracted beams.

We may perform the same experiment with a beam of light. In Figure 5 is shown a set of some two hundred vertical lines. If these lines are photographed onto a lantern slide, they form a grid through which a beam of light may be made to pass. The upper part of Figure 6 shows a beam of light as projected from a projection lantern. The middle part of the figure shows the same beam of light, but this time projected through such a lantern slide grid having about one hundred lines to the inch. See how the original spot of light is split

into three, a bright one in the center—the direct ray, and a diffracted ray on either side. It is just as in the case of the mercury ripples passing through the grid.

If this is really a case of the diffraction of waves, as we have supposed, if a grating with lines closer together is used, the separation between the diffracted images should be correspondingly greater. The lower part of Figure 6 shows our beam of light projected this time through a grid photographed with about three hundred lines to the inch. The separation of the diffracted beams is much greater.

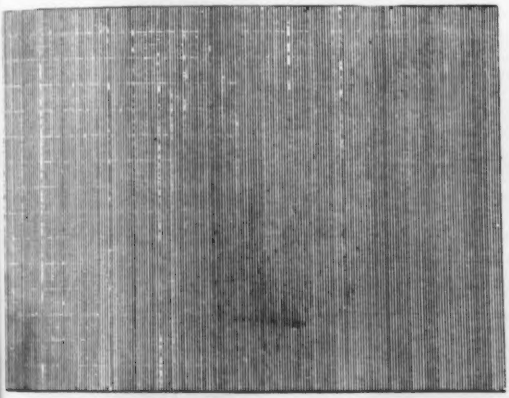


Fig. 5.

Fig. 6.

Fig. 5.—A pattern of 200 regularly spaced lines, which, when photographed onto a lantern slide, forms a diffraction grating for experiments on light.

Fig. 6.—Diffraction of light through a grid of lines. The upper portion is the direct beam, the middle portion that through 100 lines to the inch, and the lower portion photographed through a grid of 330 lines to the inch.

When these diffracted images are thrown on a screen, one can see that their outer edges are red and their inner edges blue. This means that red light is of the greater wave-length. In fact we could easily from this experiment tell what the wave-length of light is: the distance from the central image to the diffracted image is to the distance from lantern to the screen as the wave-length of the light is to the distance between the lines on the grating. When one carries through the calculation, he finds that the wave-length of light is about 150,000th of an inch.

If we can rely on such a test, light must consist of waves.

Diffraction of X-Rays.—Precisely similar experiments can, however, be made with x-rays. Figure 7 shows how we do it. In place of the projection lantern we here have an x-ray tube and a pair of slits. The slide with the lines on it is replaced by a polished mirror on which lines are ruled 50 to the millimeter. Instead of the screen we use a photographic plate. The resulting photograph is shown in Figure 8. When the ruled mirror is withdrawn we have the single vertical line D. With the grating in place we see a bright central reflected image O with companions on either side. Thus x-rays can also be diffracted, and must, therefore, like light, consist of waves.

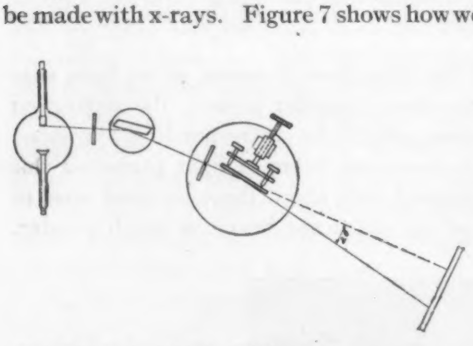


Fig. 7.—Apparatus for diffracting x-rays from a ruled reflection grating.

Light Consists of Particles

For a hundred years no one had seriously questioned the truth of the wave theory. At the close of the last century even the difficulty of supplying a suitable oscillator to give rise to the light wave seemed about to disappear through the discovery of electrons which seemed exactly suited to fill the need. But in 1900 Planck published the results of a long study of the problem of the radiation of heat and light from a hot body. This difficult theoretical study, which has stood the test of time, showed that if a body when heated is to become first red hot, then yellow and then white, the oscillators in it which are giving out the radiation must not radiate continuously as the electromagnetic theory would demand. They must rather radiate suddenly little portions of energy. The amount of energy in each portion must further, according to Planck, be proportional to the frequency. This is the origin of the celebrated "quantum" theory.

On account of the difficult character of the reasoning involved in Planck's argument, his conclusions carried weight only among those who were especially interested in theoretical physics. Among these was Einstein, who called attention to the fact that Planck's conclusions would fit exactly with the view that the radiation was not

emitted in waves at all, but as little particles each possessing a portion of energy proportional to the frequency of the oscillator as Planck had assumed.

Einstein and the Photoelectric Effect.—An opportunity to apply this idea was afforded by the photoelectric effect. It is found that when light as from an arc falls upon certain metals, such as zinc or sodium, a current of negative electricity in the form of electrons escapes from the metallic surface. This photoelectric effect is especially prominent with x-rays, for these rays eject electrons from all sorts of substances. In Figure 9 you see one of C. T. R. Wilson's

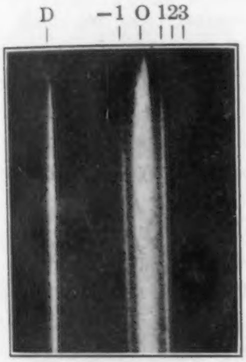


Fig. 8.—Diffraction pattern of x-rays. D is the direct beam, O the directly reflected beam, and the other lines are due to diffraction.

Fig. 9.—Photograph of the tracks of photoelectrons ejected from copper by x-rays (Wilson).

photographs of the trails left by electrons ejected by x-rays passing through air and a sheet of copper. These electrons, shot out of the air and the metal by the action of the x-rays, are the x-ray photoelectrons.

The most remarkable property of these photoelectrons is the speed at which they move. We have seen, as in Figure 10, that x-rays are the waves produced when the cathode electrons bombard a metal target inside the x-ray tube. Let us suppose that a cathode electron strikes the target at a speed of a hundred miles a second (they move tremendously fast). The resulting x-ray, after passing through the

walls of the x-ray tube and perhaps a block of wood, may eject a photoelectron from a metal plate placed on the far side. The speed of this photoelectron is then found to be almost as great as that of the original cathode electron.

The surprising nature of this phenomenon may be illustrated by an experience which I had in my early boyhood. During the summer vacations my father would take our family to a lake in northern Michigan. My older brother, who is in the audience this evening, with several of the older boys, built a diving pier around the point a half a mile away from the camp, where the water was deep. Fearing lest something should happen, my mother would not allow us younger boys to swim in this deep water. So we built a diving pier of our own in the shallower water in front of the camp. It so happened, one hot, calm July day, that my brother dove from his diving board into the deep water. The ripples from the resulting splash of course spread out over the lake. By the time they had gone around the point to where I was swimming half a mile away, they were, of course, much too small to notice. You can imagine my surprise, therefore, when these insignificant ripples, striking me as I was swimming under our diving pier, suddenly lifted me bodily from the water and set me on the diving board.

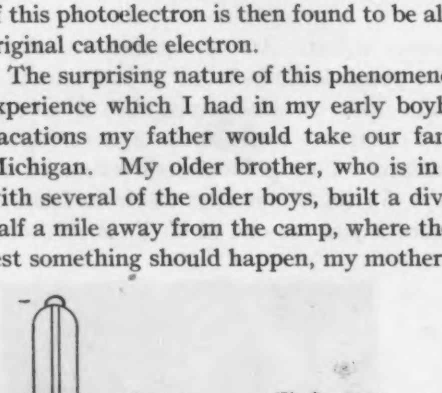


Fig. 10.—The speed of the photoelectrons ejected from the metal plate at P is almost as great as the speed of the cathode electrons which produce the x-rays at the target T.

Does this seem impossible? If it is impossible for a water ripple to do such a thing, it is just as impossible for an ether ripple, sent out when an electron dives into the target of an x-ray tube, to jerk an electron out of a second piece of metal with a speed equal to that of the first electron.

It was considerations of this kind which showed to Einstein the futility of trying to account for the photoelectric effect on the basis of waves. He saw, however, that this effect might be explained if

light and x-rays consist of particles. These particles are now commonly called "photons." The picture of the x-ray experiment on this view would be that when the electron strikes the target of an x-ray tube, its energy of motion is transformed into a photon, that is, a particle of x-rays which goes with the speed of light to the second piece of metal. Here the photon gives up its energy to one of the electrons of which the metal is composed, and throws it out with an energy of motion equal to that of the first electron.

In this way Einstein was able to account in a very satisfactory way for the phenomenon of the ejection of electrons by light and x-rays.

Peculiar X-Ray Echoes.—Even more direct evidence that light consists of particles has come from a study of x-ray echoes. If you hold a piece of paper in the light of a lamp, the paper scatters light from the lamp into your eyes. In the same way, if the lamp were an x-ray tube, the paper would scatter x-rays into your eyes. If light and x-rays are waves, scattered x-rays are like an echo. When one whistles in front of a wall, the echo comes back with the same pitch as the original sound. This must be so, for each wave of the sound is reflected from the wall, as many waves return as strike, and the frequency or pitch of the echoed wave is the same as that of the original wave. In the case of scattered x-rays, the echo should similarly be thrown back by the electrons in the scattering material, and should likewise have the same pitch or frequency as the incident rays.

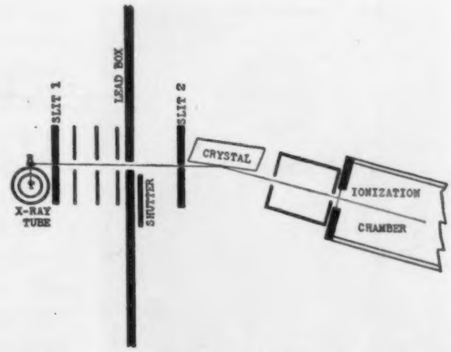


Fig. 11.—The wave-length of the x-rays scattered from a piece of carbon at R are measured by reflection from a crystal.

We measured the pitch of the x-ray echoes a few years ago at Saint Louis, using the apparatus shown in Figure 11. Rays from the target T of the x-ray tube were scattered by a block of carbon at R, and the pitch, or wave-length, of the echoed rays was measured by an x-ray spectrometer. By swinging the tube itself in line with the slits, it

was possible to get a direct comparison with the wave-length of the original rays.

Figure 12 shows the result of the experiment. Above is plotted the spectrum of the original x-ray beam. Below is shown the spectrum of the x-rays scattered in three different directions. A part of the scattered rays are of the original wave-length, but, as you see, most of them are increased in wave-length. This would correspond

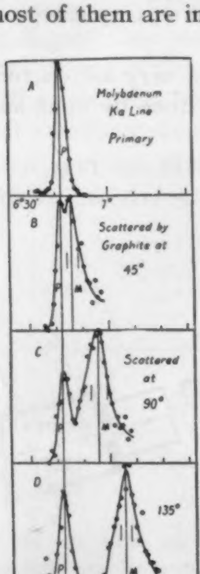


Fig. 12.

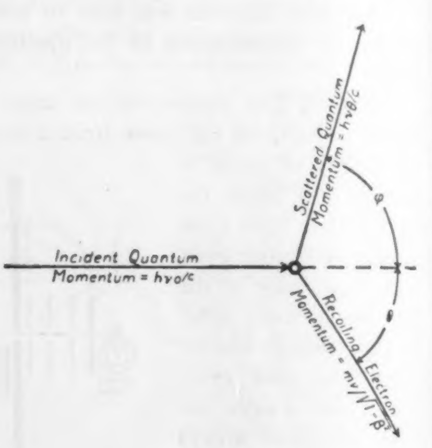


Fig. 13.

Fig. 12.—Spectra of scattered x-rays (below) compared with the spectrum of the orginal x-ray (above).

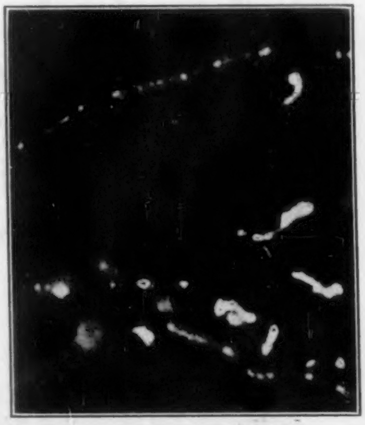
Fig. 13.—When an incident x-ray photon glances from an electron, the electron recoils from the impact, taking part of the photon's energy.

to a lower pitch for the echo than for the original sound. As we have seen, this change in wave-length is contrary to the predictions of the wave theory. If we take Einstein's idea of x-ray particles, however, we find a simple explanation of the effect. On this view, we may suppose that each photon of the scattered x-rays is deflected by a single electron, Figure 13. Picture to yourselves a golf ball bouncing from a football. A part of the golf ball's energy is spent in setting the football in motion. Thus, the golf ball bounces off, having less

energy than when it struck. In the same way, the electron from which the x-ray photon bounces will recoil, taking part of the photon's energy, and the deflected photon will have less energy than before it struck the electron. This reduction in energy of the x-ray photon corresponds, according to Planck's original quantum theory, to a decrease in frequency of the scattered x-rays, just as the experiments show. In fact, the theory is so definite that it is possible to calculate just how great a change in frequency should occur, and the calculation is found to correspond accurately with the experiments.

Playing Billiards with Photons and Electrons

If this explanation is the correct one, it should, however, be possible to find the electrons which recoil from the impact of the x-ray particles. Before this theory of the origin of scattered x-rays was suggested, no such recoiling electrons had ever been noticed. Within a few months after its proposal, however, C. T. R. Wilson succeeded in photographing the trails left when electrons in air recoil from the x-rays which they scatter. Figure 14 shows one of his typical photographs. The x-rays here are going from left to right. At top and bottom you notice the long trails left by two photoelectrons, which you recall have taken up the whole energy of a photon. In between are a number of shorter trails, all with their tails toward the x-ray tube. These are the electrons which have been struck by flying x-ray photons. Some have been struck squarely, and are knocked straight ahead. Others have received only a glancing blow, and have recoiled at an angle. Thus, we have observed not only the loss in energy of the deflected photons, as shown by the lowering in pitch of the x-ray echo, but we have found also the recoiling electrons from which the photons have bounced.



⟶ X-rays

Fig. 14.—Recoil electrons, the shorter tracks, proceed almost in the direction of the incident x-rays.

In order, however, to satisfy ourselves by a crucial test whether

x-rays act like particles, an experiment was devised which would enable us to follow at the same time the photon as it is deflected by an electron, and the motion of the recoiling electron. In Figure 15 we see at the left what we may call the x-ray gun, which shoots a few x-rays through a cloud expansion chamber. In this chamber is photographed the trail of every electron set in motion by the x-rays. So feeble a beam of x-rays is used that on the average only one or two recoil electrons will appear at a time. Let us suppose, as in the slide, that the electron struck by the x-ray particle recoils downward. This must mean that the x-ray particle has been deflected upward toward A. If this x-ray should strike another electron before it

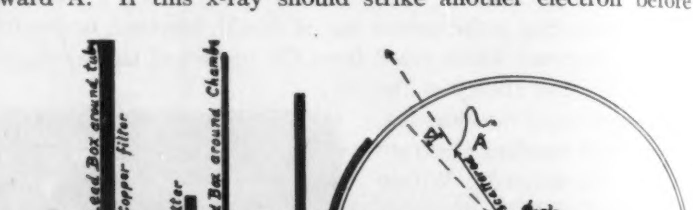


Fig. 15.—Diagram of an experiment in which one observes both the recoiling electron and the direction in which the deflected photon proceeds.

leaves the chamber, this event must occur at some point along the line OA. It cannot occur on the same side as the recoil electron. If, however, the x-ray is a wave, spreading in all directions, there is no more reason why the second electron associated with the scattered ray should appear at *A* than at *B*. A series of photographs, which shows the relation between the direction of recoil of the scattering electron *R* and the location of the second electron struck by the scattered x-ray, thus affords a crucial test between the conceptions of x-rays as spreading waves and x-rays as particles.

From a large number of photographs taken in this manner it has become evident that an x-ray is scattered in a definite direction, like

a particle. But if x-rays, so also all the rest of the family of electromagnetic radiations. It would thus seem that by these experiments Einstein's notion of light as made up of particles is established.

The Paradox of Waves and Particles

We thus seem to have satisfactory proof from our interference and diffraction experiments that light consists of waves. The photoelectric and scattering experiments afford equally satisfactory evidence that light consists of particles. How can these two apparently conflicting concepts be reconciled?

Electron Waves.—Before attempting to answer this question, let me call to your attention the fact that this dilemma applies not only to radiation but also in other fundamental fields of physics. When the evidence was growing strong that radiation, which we had always thought of as waves, had also the properties of particles, L. de Broglie of Paris asked himself, may it not then be possible that electrons, which we know as particles may have the properties of waves? An extension of Planck and Einstein's quantum theory enabled him to calculate what the wave-length corresponding to a moving electron should be. In photographs like Figure 9 we have ocular evidence that electrons are very real particles indeed. Nevertheless de Broglie's absurd suggestion was promptly subjected to experimental test by Davisson and Germes at New York, and later by Thomson at Aberdeen, and others.

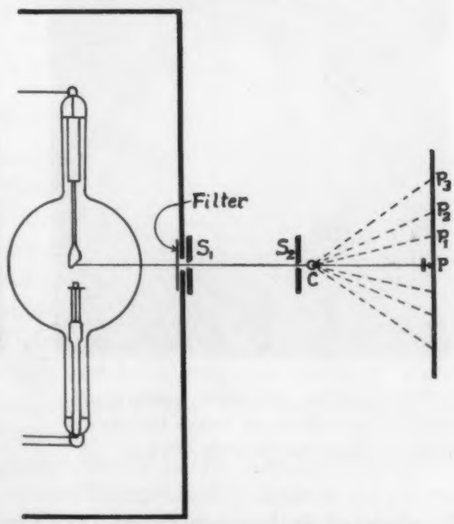


Fig. 16.—Hull's arrangement for diffracting a beam of x-rays by a mass of powdered crystals.

Let me describe Thomson's experiments, which are typical of them all. You will recall that our crucial evidence for the wave character of light was the fact that light could be diffracted by a grating of

lines ruled on glass. X-rays were diffracted in the same way; but before this had been shown possible, it was found that x-rays could be diffracted by the regularly arranged atoms in a crystal. The layers of atoms took the place of the lines ruled on glass. Figure 16 shows how this experiment has been done by Dr. Hull at Schenectady. X-rays pass through a pair of diaphragms and a mass of powdered crystals placed at C, and strike a photographic plate at P. Rays diffracted by the layers of atoms in the crystal strike at such points as P_1, P_2, etc., giving rise to a series of rings about the center. If a mass of powdered aluminum crystals is placed at C, Hull obtains

Fig. 17.—The diffraction pattern produced when a beam of x-rays traverses a mass of aluminum crystals (Hull).

Fig. 18.—The diffraction pattern produced when a beam of electrons traverses a mass of gold crystals (G. P. Thomson).

the photograph shown in Figure 17. You see the central image, and around it the diffraction rings. It was this crystal diffraction that first gave convincing evidence that x-rays, like light, consist of waves.

G. P. Thomson has performed a precisely similar experiment with electrons. The x-ray beam in the last slide was replaced by a beam of cathode electrons, and gold leaf took the place of the aluminum. The resulting photograph is shown in Figure 18. Though it is not quite as sharp as the photograph taken with the x-rays, we can see distinctly the central image, and several rings of diffracted electrons. If the last slide demonstrated the wave character of x-rays, does not this slide prove equally definitely the wave character of electrons?

Most of you are aware of the fact that J. J. Thomson, the famous old Cavendish Professor of Physics at Cambridge, was largely responsible for proving that cathode rays are electrified particles. About a year ago my wife and I were paying Sir Joseph and Lady Thomson a Sunday afternoon call, and found their son, G. P. Thomson, home from Aberdeen for a week-end. He had with him this photograph, Figure 18, showing the diffraction of cathode rays by crystals of gold. It was a really dramatic occasion to see the great old man of science, who had spent his best years showing that electrons are particles, full of enthusiasm over his son's achievement of finding such convincing evidence that moving electrons are waves.

We are thus faced with the fact that the fundamental things in nature, matter and radiation, present to us a dual aspect. In certain ways they act like particles, in others like waves. The experiments tell us that we must seize both horns of the dilemma.

A Suggested Solution

During the last year or two there has gradually developed a solution of this puzzle, which, though at first rather difficult to grasp, seems to be free from logical contradictions and essentially capable of describing the phenomena which our experiments reveal. A mere mention of some of the names connected with this development will suggest something of the complexities through which the theory has gradually gone. There are Duane, Slater and Swann in this country, de Broglie in France, Heisenberg and Schrödinger in Germany, Bohr in Denmark, Dirac in England, among others, who have contributed to the growth of this explanation.

The point of departure of this theory is the mathematical proof that the dynamics of a particle may be expressed in terms of the propagation of a group of waves. That is, the particle may be replaced by a wave train—the two, so far as their motion is concerned, may be made mathematically equivalent. The motion of a particle such as an electron or a photon in a straight line is represented by a plane wave. The wave-length is determined by the momentum of the particle, and the length of the train by the precision with which the momentum is known. In the case of the photon, this wave may be taken as the ordinary electromagnetic wave. The wave corresponding to the moving electron has received no generally accepted name, other than the Greek letters $\psi\psi$. Perhaps we may call it, however, by the name of its inventor, a de Broglie wave.

Consider, for example, the deflection of a photon by an electron on this basis, that is, the scattering of an x-ray. The incident photon is represented by a train of plane electromagnetic waves. The recoiling electron is likewise represented by a train of plane de Broglie waves propagated in the direction of recoil. These electron waves form a kind of grating by which the incident electromagnetic waves are diffracted. The diffracted waves represent in turn the deflected photon. They are increased in wave-length by the diffraction because the grating is receding, resulting in a Doppler effect.

In this solution of the problem we note that before we could determine the direction in which the x-ray was to be deflected, it was necessary to know the direction of recoil of the electron. In this respect the solution is indeterminate; but its indeterminateness corresponds to an indeterminateness in the experiment itself. There is no way of performing the experiment so as to make the electron recoil in a definite direction as a result of an encounter with a photon. It is a beauty of the theory that it is determinate only where the experiment itself is determinate, and leaves arbitrary those parameters which the experiment is incapable of defining.

It is not usually possible to describe the motion of either a beam of light or a beam of electrons without introducing both the concepts of particles and waves. There are certain localized regions in which at a certain moment energy exists, and this may be taken as a definition of what we mean by a particle. But in predicting where these localized positions are to be at a later instant, a consideration of the propagation of the corresponding waves is usually our most satisfactory mode of attack.

Attention should be called to the fact that the electromagnetic waves and the de Broglie waves are, according to this theory, waves of probability. Consider as an example the diffraction pattern of a beam of light or of electrons, reflected from a ruled grating, and falling on a photographic plate. In the intense portion of the diffraction pattern there is a high probability that a grain of the photographic plate will be affected. In corpuscular language, there is a high probability that a photon or electron, as the case may be, will strike this portion of the plate. Where the diffraction pattern is of zero intensity, the probability of a particle striking is zero, and the plate is unaffected. Thus there is a high probability that a photon will be present where the "intensity" of an electromagnetic wave is great, and a lesser probability where this "intensity" is smaller.

It is a corollary that the energy of the radiation lies in the photons,

and not in the waves. For we mean by energy the ability to do work, and we find that when radiation does anything it acts in particles. In this connection it may be noted that this wave-mechanics theory does not enable us to locate a photon or an electron definitely except at the instant at which it does something. When it activates a grain on a photographic plate, or ionizes an atom which may be observed in a cloud expansion chamber, we can say that the particle was at that point at the instant of the event. But in between such events the particle cannot be definitely located. Some positions are more probable than others, in proportion as the corresponding wave is more intense in these positions. But there is no definite position that can be assigned to the particle in between its actions on other particles. Thus it becomes meaningless to attempt to assign any definite path to a particle. It is like assigning a definite path to a ray of light: the more sharply we try to define it by narrow slits, the more widely the ray is spread by diffraction. In fact, it is only to satisfy our sense of continuity that we assume that an electron or photon has a real existence between the occasions at which it acts on other particles. It would be equally permissible to suppose that light or cathode rays alternate in form between particles and waves. While moving from one place to another they would spread out as waves, but when producing any physical effect they would materialize into discrete particles.

Perhaps enough has been said to show that by grasping both horns we have found it possible to overcome the dilemma. Though no simple picture has been invented affording a mechanical model of a light ray, by combining the notions of waves and particles a logically consistent theory has been devised which seems essentially capable of accounting for the properties of light as we know them.

Radio rays, heat rays, visible and ultraviolet light, x-rays, gamma rays and cosmic rays, all are thus different varieties of light. We find from our experiments on diffraction and interference that light consists of waves. The photoelectric effect and the scattering of x-rays give equally convincing reasons for believing that light consists of particles. For centuries it has been supposed that the two conceptions are contradictory. Goaded on, however, by obstinate experiments, we seem to have found a way out. We continue to think of light propagated as electromagnetic waves; but whenever the light does something, it does it as photons. In reply to our question, what is light? the answer seems to come, waves and particles, light is both.

PRESIDENT'S REPORT

At the May meeting of the Executive Committee, the following institutions were asked to prepare and submit an informal petition: Clark University, University of Wyoming, University of Rochester.

An official visitor was appointed to the following institutions: Pennsylvania State College, State College of Washington, University of Oklahoma.

Preliminary inquiries from 17 institutions and groups have been received and are under consideration. Some of them bring up the question of establishing chapters at separate branches of universities. We have already established a chapter at the Medical School of the University of Illinois in Chicago.

Sigma Xi clubs have been established at Louisiana State University and the Medical College of Virginia at Richmond.

The University of Missouri Chapter has published through the Yale University Press a series of lectures delivered at chapter meetings on the general topic of "Growth." These lectures are the results of investigations which have been under way at the university for a long period of years. So far as we have information, it is the second effort in this direction by Sigma Xi chapters, the first being the publication of two series of lectures delivered at Yale before the chapter there.

F. R. MOULTON, *President*

SECRETARY'S REPORT FOR THE YEAR 1928

1. MEMBERSHIP:

The total membership of the Society is 22,151, of which slightly over 8000 are enrolled in the fifty chapters. During the current year, 757 members and 828 associates have been added, and 218 associates were promoted to membership.

The chapters reported more promptly in 1928 than in previous years, and the list of chapters that have not reported at this date is smaller than in previous years. We still get cards without addresses, written in ink and even with pencil instead of being typed, and occasionally cards reach us that are quite illegible. We also receive cards that are not uniform with the cards which the Society provides gratis. All of this necessitates additional work in the Secretary's office, since we must return to secretaries the cards that are incomplete or transfer to our record cards the information sent us on cards which the chapters themselves have devised.

The records in the Secretary's office now show the number of elections as associates and members from each chapter, so that in future years a comparison will be possible, not only of total additions to the Society enrollment, but of additions in the individual chapters.

2. FILES OF THE SOCIETY:

The Secretary's office has three files—the chapter file, alphabetical file and geographical file. All of these are important and extremely useful. In the chapter file, members and associates are grouped in accordance with the chapter into which they have been initiated In the alphabetical file, the cards show the year of election, whether associate or member, whether chapter member of alumnus, whether a contributor to the Fellowship Fund on the present plan or the original five-year plan and the amount contributed, and whether a subscriber to the official journal. The geographical file locates the membership in states, cities and towns of the United States. Owing to rapid expansion we have this month been obliged to extend this subdivision to Canada also. In addition, this file locates members and associates in 55 foreign countries.

All of these files are very useful, especially the geographical file.

It has been possible to furnish lists of Sigma Xi residents in certain sections as follows:

To the Lehigh Chapter, those resident in Bethlehem and vicinity.

To Professor Baitsell, those resident in Harvard and Princeton.

To Professor deForest, those resident in the vicinity of Los Angeles.

To the Pennsylvania Chapter, those resident in Philadelphia and vicinity.

To the University of Pittsburgh Club, those in Pittsburgh and vicinity.

To the Worcester Chapter, those resident in Worcester.

To Mr. D. H. Sweet, those resident in four states neighboring Chicago.

To Mr. C. E. Davies, those resident in two states in vicinity of New York City.

These above lists comprise 544 towns and give 4896 names.

The geographical file will be of immense help in the future, as the alumni movement expands.

It has been necessary to develop a "no address" file. At present this numbers 3128 names, and includes those for whom we have no address at all, an insufficient or incorrect address. We constantly strive to reduce this number, and are planning to make use of an advertisement in an early number of the QUARTERLY asking the assistance of subscribers in locating those whom our letters do not reach. We have tried ourselves to reduce this number by referring to the Alumni Recorders at the institutions where we have chapters. In many cases, they have been unable to supply us with the needed information. We have also sent out inquiry cards to the last address on our files, asking correct information. We are indebted to Mr. Davies for helpful suggestions in this work.

3. ALUMNI FUND:

In the early part of the year, we sent out approximately 14,000 letters, and there were returned through the post office 788. Last year we sent out about 13,000 letters, of which 2502 were returned. This shows that our address list is more accurate now than it has been in the past.

The number of alumni contributing during 1928 is 1350 as against 1339 in 1927. Of those contributing this year, 215 are on the basis of the original five-year plan.

The total amount received by this office for the current year and

transferred to the treasurer is $3430, of which $2170 has been awarded to five applicants. Last year, the amount collected was $3601.92, of which $2025 was awarded to eight candidates. These figures are interesting. With the installation of new chapters, we have lost 211 contributors to the Alumni Fund who are now dues-paying members of the chapters, that is, members who are not solicited for contributions to the Alumni Fund. It is also to be noted that more of the number contributing are falling into the $3 class. We have had fewer subscribers, those giving $5 and $10, than in previous years. It appears from these figures that we have made a substantial gain in the number of alumni contributing to the fund, since, in spite of the loss of 211 former paying alumni, we have 1348 subscribers to the fund—a net gain of 221.

In connection with the Alumni Fund, it is gratifying to note that the University of Pittsburgh Sigma Xi Club has aided the work of circularization by canvassing its members for contributions, and the Oklahoma Club has continued its subscription of $25 to the fund, a contribution it has been making for several years.

5. FELLOWSHIPS:

We have already received fourteen applications for Fellowships for the coming academic year, a number quite in excess of those received in previous years at this season.

6. THE QUARTERLY:

We have published approximately 110 pages in four numbers of the QUARTERLY, as against 101 pages in 1927. The March issue, which we call the Convention number, contains, in addition to the Proceedings of the Convention and annual reports of the officers, Dr. Little's address given at Nashville and Professor Crew's article on "What Group of Sciences Does Sigma Xi Represent?" The June QUARTERLY contains Dr. Whitney's address at the meeting of the Chicago alumni and the article by Dr. Myers of the University of Minnesota on "Our Knowledge of Lung Diseases." The September number contains, in addition to the report of the committee on Sigma Xi grants and of the holders of the grants for 1927–1928, an article by Mr. Sweet on the objects of our research funds and how those objects are being met. The December issue is devoted to reports of chapters and club activities for the last academic year.

The total circulation is approximately 9000, apportioned as follows:

Alumni contributors	822
Independent subscribers	20
Chapter members	7958

In connection with these figures, it is interesting to note that there are 393 new alumni subscribers this year and 1395 new chapter member subscribers.

The number taking the QUARTERLY has trebled since 1922.

We have referred in previous reports to the great difficulty we are experiencing in keeping the subscription list accurate. This is in part due to the fact that at present we get the lists of chapter enrollments between January and June, and the lists become inaccurate soon after they are received, since the chapter enrollments change again in September when the new academic year begins. We must work out some plan by which we can make our changes in addresses in the early fall. This will save much work in the Secretary's office.

We have been forced to make a rule that changes of address to be effective for any issue of the QUARTERLY must reach us by the first of the month preceding that issue.

7. INSIGNIA:

Up to December 17 we had sold 850 keys and 304 associate pins, and the total net income was $1003. This amount has been transferred to the treasurer. This item in 1927 amounted to $600. We have received orders from every chapter except one, so this income of $1000 probably represents the maximum to be expected from our sale of insignia.

Comparing these figures with the total number of members and associates elected during the year, it is apparent that probably every *new member* purchases a key, but less than 50% of the *new associates* purchase a pin.

8. MISCELLANEOUS:

Since May of this year, the Secretary's office has sent out 1200 certificates and diplomas and 980 index cards. This is in addition to the circular letter to alumni and the usual correspondence. The office does all the mimeographing of circular letters.

The work of checking address lists and making corrections and notations such as promotions, removals from and to the alumni body compiling the address lists for the publisher is, of course, constant.

SUMMARY

I. MEMBERSHIP:		1928	1927
Total (approx.)		22,151	20,500
Number having no address, wrong address or incomplete address		3,128	3,280
Chapter enrollment (50 chapters)		8,009	6,200
Members elected 1928	757		
Associates elected 1928	828		
Associates promoted in 1928	218		

II. ALUMNI FUND:	1928	1927
Number letters sent out	14,000	13,000
Number letters returned	788	2,502
Number contributing	1,350	1,339
Amount contributed	$3430.00	$3601.92

(By installation of new chapters, 211 former contributors have become dues-paying chapter members.)

III. QUARTERLY:	1928	1927
Number of pages	110	101
Number printed each issue (approx.)	9000	7000
Alumni	822	1150
Independent subscribers	20	
Chapter enrollment	7958	6200
Number new alumni subscribers	393	
Number new chapter subscribers	1395	

(Circulation has trebled in six years.)

IV. INSIGNIA (to Dec. 17, 1928):	1928	1927
Number of keys sold	850	497
Number of pins sold	304	191
Total NET INCOME therefrom	$1003.00	$600.00

It appears that every new member purchased a key and about 37% of the new associates purchased a pin.

V. APPLICATIONS FOR SIGMA XI GRANTS:

No announcement of available grants for 1929–30 has as yet been made, yet we already have 15 applications for a grant. This number is in excess of those received at this season in any year since the Fund was started.

EDWARD ELLERY, *Secretary*

REPORT OF THE TREASURER OF SIGMA XI FOR THE YEAR 1928

The assessments of all chapters except three, the California Institute of Technology, the University of Nebraska and the University of Oregon, were paid during the calendar year. These have been paid since.

RECEIPTS

Cash on hand, January 1, 1928	$2193.39	
Chapter assessments for 1928	4886.00	
Chapter assessments, arrears for 1927	319.50	
Initiation fees	1875.00	
Installation fees	200.00	
Sale of QUARTERLY	32.00	
Sale of Insignia	1003.00	
Interest on investments	440.00	
Interest on Savings Bank Account	81.45	
Southern California Edison Co. bond, redeemed	1050.00	
Surplus—Dinner tickets at Nashville	12.75	
Credit clerical assistance on Alumni Fund (authorized by Executive Committee)	400.00	$12,493.09

DISBURSEMENTS

Secretary's office:		
Secretary's assistant	$1923.50	
General	316.75	
Secretary's stipend	1800.00	
Treasurer's office, clerical assistance	50.00	
Officers' travel expense	920.35	
Engrossing charters	174.15	
QUARTERLY (4 issues)	1708.71	
1 Philadelphia Co. bond	979.50	
1 Erie Railroad bond	947.00	
1 Southern Railway bond	1152.00	
Miscellaneous	47.48	
Cash on hand, January 1, 1929	2473.65	$12,493.09

INVESTMENT ACCOUNT

(Securities carried at cost)

$1000 American Telephone & Telegraph Co. 5 1/2% bond, carried at	$1037.44
$1000 American Telephone & Telegraph Co. 5% bond, carried at	991.94

$1000 Consolidated Gas of New York 5½% bond, carried at	1002.90	
$1000 St. Louis and San Francisco Railway 4% bond, carried at	796.35	
$1000 Baltimore and Ohio Railroad 5% bond, carried at	955.00	
$1000 Pacific Gas and Electric Co. 5½% bond, carried at	1045.00	
$1000 Philadelphia Co. bond, carried at	979.50	
$1000 Erie Railroad Co. 5% bond, carried at	947.00	
$1000 Southern Railway Co. 6% bond, carried at	1152.00	$8,907.13

Alumni Fund

Receipts

Cash on hand, January 1, 1928	$2454.59	
Receipts for the year from subscriptions	3552.76	
Checks put through for collection 1927	5.70	$6013.05

Disbursements

Research:			
Miss Joyce Hedrick	$360.00		
Mrs. M. M. Brooks	160.00		
Professor Elbert C. Cole	25.00		
Professor Edward Mack, Jr.	170.00		
Professor Carl L. A. Schmidt	312.50		
Mr. Arthur A. Vernon	281.25		
Dr. Elizabeth Adams	100.00	$1408.75	
Secretary's office (supplies)		389.88	
Allotment to Secretary's office for clerical work on alumni lists and correspondence		400.00	
Collection on foreign checks		.65	
Cash on hand, January 1, 1929		3813.77	$6013.05

Dec. 31, 1928 GEORGE B. PEGRAM, *Treasurer*

We have audited the accounts of the Treasurer of the Society of Sigma Xi for the year ending December 31, 1928, and certify that the income shown by the books of the Treasurer has been duly accounted for, that payments have been properly vouched and that the balance sheet and accounts submitted contain a true statement of the financial condition of the Society. We have also examined the securities in the hands of the Treasurer and find the following bonds: $1000 American Telephone and Telegraph Co., $1000 American Telephone and Telegraph Co., $1000 Consolidated Gas of New York, $1000 St. Louis and San Francisco Railway, $1000 Baltimore and Ohio Railroad, $1000 Pacific Gas and Electric Co., $1000 Philadelphia Co., $1000 Erie Railroad Co., $1000 Southern Railway Co.

FREDERICK W. HEHRE
WALTER A. CURRY
Date: February 14, 1929 *Auditors*

CHAPTER OFFICERS

LIST FURNISHED BY THE SECRETARIES OF THE CHAPTERS

CHAPTER	PRESIDENT	VICE-PRES.	SECRETARY	TREASURER
Cornell........	O. A. Johannsen	F. O. Ellenwood	W. A. Hagan...	A. J. Eames
Rensselaer.....	L. W. Clark....	G. K. Palsgrove	E. M. Clark....	W. J. Williams
Union.........	M. F. Sayre ...	F. W. Grover..	C. B. Hurd....	C. B. Hurd
Kansas........	E. B. Stouffer..	H. H. Lane....	J.D. Stranathan	H. E. Jordan
Yale..........	J. I. Tracy....	S. R. Brinkley	A. F. Hill......	L. E. Seeley
Minnesota.....	J. A. Harris....	K. W. Stenstrom.......	J. W. Buchta..	W. S. Cooper
Nebraska......	M. H. Swenk..	N. A. Bengtson	E. N. Andersen	M. G. Gaba
Ohio..........	W. J. McCaughey	Paris B. Stockdale.........	P. W. Ott.....	F. A. Hitchcock
Pennsylvania..	T. D. Cope....	R. H. True....	W. H. Barton, Jr.	W. R. Taylor
Brown........	J. W. Wilson ..	A. E. Watson..	C. W. Miller...	C. R. Adams
Iowa..........	J. T. McClintock.........	J. F. Reilly....	Lee Travis.....	G. W. Martin
Stanford.......	C. L. Alsberg..	G. M. Smith...	G. R. Harrison	G. R. Harrison
California.....	E. D. Merrill...	C. W. Porter...	S. K. Allison...	F. H. Cherry
Columbia......	A. T. Poffenberger.......	L. T. Work....	P. F. Kerr....	P. F. Kerr
Chicago.......	Julius Stieglitz.	H. G. Wells....	M. E. Hanke..	M. E. Hanke
Michigan......	H. M. Randall.	H. E. Lewis....	C. E. Guthe...	R. C. McAlpine
Illinois........	M. L. Enger...	W.H.Rodebuch	A. C. Bevan...	T. H. Frison
Case..........	Anthony Jenkin	T. D. Owens...	J. R. Martin...	T. M. Focke
Indiana.......	F. C. Mathers .	J. E Switzer ...	A. C. Kinsey ..	Paul Weatherwax
Missouri.......	H. D. Hooker..	M. P. Weinbach	M. G. Mehl....	H. H. Charlton
Colorado......	W. B. Pietenpol	Clarence Eckel.	C. F. Poe......	F. S. Bauer
Northwestern..	W. G. Waterman.........	E. H. Hatton...	L. I. Bockstahler...........	Lois W. Griffiths
Syracuse......	H. N. Eaton..	R. S. Boehner..	Mrs. M. N. Harwood........	C. C. Forsaith
Wisconsin.....	G. W. Keitt...	H. A. Schuette	R. A. Brink...	A. K. Lobeck
University of Washington	R. C. Miller...	Hewitt Wilson.	G. E. Goodspeed	V. Sivertz
Worcester.....	M. E. Smith...	G. H. MacCullough	H. J. Gay......	Harris Rice
Purdue........	E. B. Mains....	R. B. Wiley...	W. E. Edington	H. MacGillivray
Washington University...	P. A. Shaffer...	A. S. Langsdorf	H. Lee Ward..	L. F. Thomas
District of Columbia....	W. T. Lee.....	E.C.Crittenden	A. E. Eckhardt	M. A. Griffith
Texas.........	H. J. Muller...	H. L. Lochte...	O. R. Chambers	Arnold Romberg
Mayo Foundation.......	Chas. Sheard..	H. E. Robertson	A. E. Osterberg	A. E. Osterberg
N. Carolina....	W. F. Prouty..	O. Stuhlman, Jr.	J. N. Couch....	J. N. Couch
N. Dakota.....	A. G. Leonard	E. E. Harris...	E. A. Baird....	E. A. Baird
Iowa State College (formerly *Ames*)	R. M. Hixon...	C. J. Drake....	O. W. Park....	A. L. Bakke
Rutgers.......	R. C. H. Heck.	Richard Morris	W. R. Robbins.	T. J. Murray
McGill........	H. M. Mackay.	J. C. Meakins.. W. G. McBride	D. A. Keys....	J. Beattie
Kentucky.....	George Roberts	W. R. Allen...	M. N. States..	G. D. Buckner
Idaho.........	C. W. Hungerford........	E. E. Hubert...	J. H. Johnson..	F. W. Gail
Swarthmore....	W. R. Wright..	Arnold Dresden	H. J. Creighton	H. J. Creighton
Oregon........	E. H. McAllister	G. E. Burget	Ethel Sanborn	H. G. Tanner

CHAPTER OFFICERS (*Continued*)

LIST FURNISHED BY THE SECRETARIES OF THE CHAPTER

CHAPTER	PRESIDENT	VICE-PRES.	SECRETARY	TREASURER
Virginia.......	L. G. Hoxton..	W. A. Kepner..	J. K. Roberts..	J. K. Roberts
Johns Hopkins	Knight Dunlap	S. R. Damon...	M. W. Pullen..	F. D. Murnaghan
Calif. Institute of Technology	R. C. Tolman..	J. A. Anderson.	W. H. Clapp...	S.S. Mackeown
New York University...	Joseph W. Roe.	Eric Jette	H. W. Stunkard	H. W. Stunkard
Univ. of Cincinnati.......	G. D. McLaughlin...........	W. H. Bucher..	S. B. Arenson..	S. B. Arenson
Michigan State College	V. R. Gardner.	F. C. Bradford.	R. M. Snyder..	E.F. Woodcock
Arizona	T. F. Buehrer..	J. C. Clark	H. B. Leonard	H. B. Leonard
Lehigh.........	V. Babasinian..	B. Stoughton...	L. L. Smail....	C. C. Bidwell
Maryland	C. O. Appleman	E. C. Auchter..	M. M. Haring..	M. M. Haring
Kansas State College	E. C. Miller ...	Margaret Justin	C. W. Colver...	G. E. Raburn
Col. of Medicine Univ. of Illinois.........	D. J. Davis	....	W. H. Welker..	I. Pilot

SIGMA XI CLUBS

CLUB	PRESIDENT	VICE-PRES.	SECRETARY	TREASURER
Oklahoma.....	P. B. Sears....	C. N. Gould...	Wm. Schriever.	Wm. Schriever
Southern California...	S. T. Barnett..	R. J. Reed.....	H. de Forest...	H. de Forest
Duluth........	....	....	E. W. Kelly....	....
Carleton College.......	E. A. Fath	E. O. Ellingson	H. P. Klug	H. P. Klug
University of Denver......	T. R. Garth....	R.E.Nyswander	E. A. Engle....	W. H. Hyslop
Oregon State Agricultural College......	C. E. Thomas..	....	R. A. Osborn...	R. A. Osborn
West Virginia University...	A. M. Reese....	J. H. Gill......	R. P. Davis....	....
University of Maine.......	D. B. Young..	C. R. Phipps ..	C. B. Crofutt..	C. B. Crofutt
University of Pittsburgh...	O.H. Blackwood	L. P. Sieg	A. E. Emerson.	A. E. Emerson
University of Wyoming....	Aven Nelson...	J. A. Hill......	O. H. Rechard.	O. H. Rechard
University of Florida......	J. R. Benton...	O. F. Burger..	O. C. Bryan ...	O. C. Bryan
University of Rochester...	W. R. Bloor....	W. L. Berry....	L. C. Boynton..	L. C. Boynton
Colorado Agricultural College........	G. T. Avery...	L. D. Crain....	L. W. Durrell..	L. W. Durrell
State College of Washington	H. E. Culver...	....	Hannah C. Aase	....
University of South Dakota	E. P. Rothrock	....	H. C. Abbott..	H. C. Abbott
Louisiana State University...	L. J. Lassalle ..	H. V. Howe...	E. H. Behre...	E. H. Behre
University of Alabama.....	E. B. Carmichael........	G. I. Adams...	W. P. Ott.....	W. P. Ott
University of California at Davis.......	T. I. Storer....	....	E. L. Proebsting	E. L. Proebsting

OFFICIAL ANNOUNCEMENTS

All insignia of the Society are available only through the office of the national secretary. Orders for these insignia are issued through chapter secretaries, and must be **prepaid.** Information about styles and prices may be obtained from chapter secretaries or the national secretary.

PRINTED BLANKS

The General Convention has instructed the secretary to forward to chapters under the following stipulations:

Membership Certificates, stamped with the great seal of the Society. In packages of fifty prepaid, on advance payment of $2.50 for each package. Please specify carefully whether for active or associate members.

Index Cards, for members and associates. *Gratis.*

Chapter secretaries are requested to fill out these cards carefully giving PERMANENT addresses of the members, and return to the national secretary.

A few copies of the Quarter Century Record are available at $2.50 each.

Copies of the Constitution are available at 7 cents each.

SIGMA XI BANNERS

Chapters may obtain Sigma Xi Banners at the following prices:

Size 3 x 5—$ 8.00
4 x 6— 12.00
5 x 8— 20.00

CHANGES OF ADDRESS

All changes of address and all other correspondence should be addressed to the secretary of Sigma Xi, Edward Ellery, Union College, Schenectady, N. Y.